MAGNETIC RESONANCE IMAGE WAVELET ENHANCER

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Abstract− **Echo−Planar Imaging is able to generate images in less than 80 ms, however, images have poor quality since they have an intrinsic poor Signal−to−Noise ratio. Filtering techniques can be applied to enhance the image quality such as Fourier transform. Another natural tool is the so−called wavelet transform, this is an analytical tool capable of generating an analysis in time and frequency simultaneously. The two−dimensional wavelet transform is applied to blood flow maps produced with a flow encoding Echo−Planar Imaging sequence to improve the image Signal−to−Noise ratio. Enhanced flow maps and contour maps are presented. The wavelet transform shows that flow magnetic resonance images can be improved without detriment of the spatial resolution and unmasking the relevant anatomical and physiological information.**

I. INTRODUCTION

The study of the human hemodynamics has been benefited since the introduction of various imaging modalities such as Magnetic Resonance Imaging (MRI), Positron Emission Tomography (PET) and Ultrasound (US). These relatively new powerful tools have provided researchers with the means to study the cardiovascular disease using minimally invasive or non−invasive techniques.

Among these imaging methods MRI has become the most popular tool due to its non invasive property and the capability to generate images with a natural contrast and high spatial resolution at high magnetic fields.

Unlike other Magnetic Resonance Angiography (MRA) techniques, Echo−Planar Imaging (EPI) is able to generate images in real time (less than 80 ms), this particular characteristic makes it an ideal candidate to study blood flow in the cardiovascular system [1]. Although other flow encoded MRI methods have been proposed, only Echo−Planar Imaging has reached the clinical status so a high number of MR imagers are equipped with this technology worldwide

It has been previously proved that flow encoded EPI can quantify blood flow in the great vessels and cardiac chambers [2]. However, its major drawbacks is its poor signal−to−noise ration (SNR) of the image, see Fig. 1. The relevant information about the anatomical structures and the physiological dynamics is hidden within the image [1−2]. By filtering out the irrelevant information and retaining the

relevant information, the image SNR can be significantly improved. By filtering out any image we are showing the information in a more suitable manner so image interpretation can be easily done. There is an extensive variety of filtering methods used in different type of images, such as, images generated by a) MR imagers, b) X−ray machines, c) CT and SPECT scanners, d) ultrasound methods, etc [3].

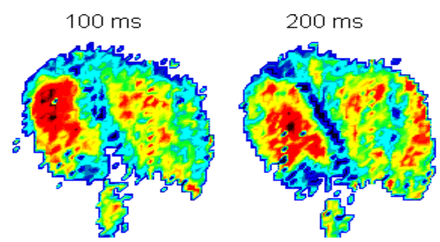

Figure 1. Original flow maps acquired with Half Fourier Echo−Planar Imaging. Flow and anatomical information is masked due to the intrinsic poor signal−to−noise ratio.

A particular method to enhance X−ray images might not certainly be well suited to enhance the quality of MRI flow images, for example. The enhancement techniques are usually used to remove blurring and distortions, to smooth out the image noise, and to better the contrast and SNR [3].

The poor quality image can be overcome by applying an enhancement technique such as Fourier analysis or wavelet transform. Human hemodynamics is characterised by local fluctuations occurring in a very time small scale. Fourier analysis is not the best analytical tool to perform since local changes of the function might drastically alter all Fourier coefficients.

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It has recently been showed that the wavelet transform can provide us with tool able to perform a more efficient local analysis of flowing fluids [4]. This natural extension of the Fourier transform can sort magnetic resonance image data into components at all scales, and then each component with a resolution equal to its scale can be studied. Thus, the wavelet transform can perform an analysis in both space and scale simultaneously.

Wavelets can yield a natural multiresolution of every image, together with the all−important edges: blur is represented by the low frequency part of the Fourier transform.

We previously applied the Daubechies 2D wavelet [5] to our velocity maps of the heart, since it is particularly well suited to analyse the fractal properties of the image [6].

In 1989, Daubechies [7] proposed a new wavelet composed by an orthonormal wavelet bases (multiresolution analysis) with vanishing moments not only for ϕ (scaling function), but also for ψ (wavelet function). In this case, the Coiflet wavelet was natural extended to a bidimensional transform to compute the two−dimensional flow maps. Then, the two−dimensional wavelet can be defined as the product of two one−dimensional wavelets: $\phi(x,y)= \phi(x)\,\phi(y)$.

Coiflets wavelet is a particular case of the Bezout equation and is expressed as:

$$P_1 = \sum_{K=0}^{k-1} \binom{K-1+k}{k} \left(\sin^2 \xi/2\right)^k + \left(\sin^2 \xi/2\right)^K f(\xi)$$

where *f* is an arbitrary trigonometric polynomial and the two following conditions must be satisfied:

$$m_0(\xi) = \left(\left(1+\exp\left(-i\hat{\imath}\right)\right)/2\right)^{2K} P_1(\xi)$$

$$\left|m_0(\xi)\right|^2 + \left|m_0(\xi+\pi)\right|^2 = 1$$

II. Methodology

Blood flow maps were acquired with a partial Fourier method combined with Echo−Planar Imaging and preparation spin sequence to encode flow along one direction. This sequence was denominated flow encoded Half Fourier Echo−Planar Imaging, HF−EPI for short. Velocity maps are depicted some in Fig. 1.

In order to enhance the image SNR, programmes were specially written in MATLAB™ language to evaluate all the 14 cardiac velocity maps of a healthy volunteer with the 2D Coiflets wavelet. These maps were taken at every 50 ms within one single cardiac cycle. Thus, 2D approximation and detail coefficients of the bidimensional Coiflets wavelet were computed at level 2 for simplicity.

III. Results

Images were formed with the resulting 2D approximation coefficients using level 2 of decomposition for simplicity. We only used the approximation coefficients since it was not possible to generate good SNR images with the detail coefficients. These coefficient images are shown in Fig. 2. Contour maps were computed to investigate if hemodynamic patterns can be observed as well.

V. Conclusion

From images in Figs. 1 & 2, it can be appreciated an important improvement of the image SNR achieved with the Coiflets 2D wavelet, despite the fact that only one decomposition level has been used. This is in good accordance with the previous results obtained with the Daubechies wavelet These improved−SNR flow maps can display flow and anatomical information in a simpler manner.

It is possible to discriminate flow patterns that might characterise blood flow in the cardiac chambers and descending aorta. To recognise these particular hemodynamic patterns, we may apply fractal analysis to our wavelet−enhanced velocity maps. It is also important investigate for which values of n and scale can simplify flow visualisation, so more relevant flow information can be extracted from our blood flow maps.

Echo−Planar Imaging together with the Coiflets continuous transform might be used to offer a real−time tool to gain insight into the behaviour of blood flow in the human cardiovascular system.

Blood flow can be easily visualised in the cardiac chambers and in the descending aorta. Unlike the cardiac contour maps published in [1] which represent the behaviour of blood flow considering all the coefficients, these enhanced flow maps shown local variations in time for each velocity map.

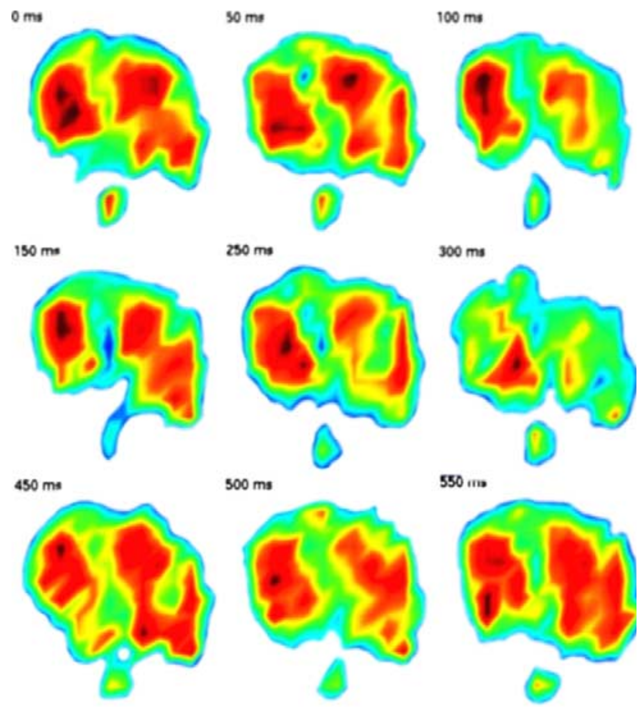

Figure 2. Two−dimiensional blood flow maps enhanced with the bidimensional Coiflets wavelet. Flow images show a great improvement compared with the original flow maps in Fig. 1.

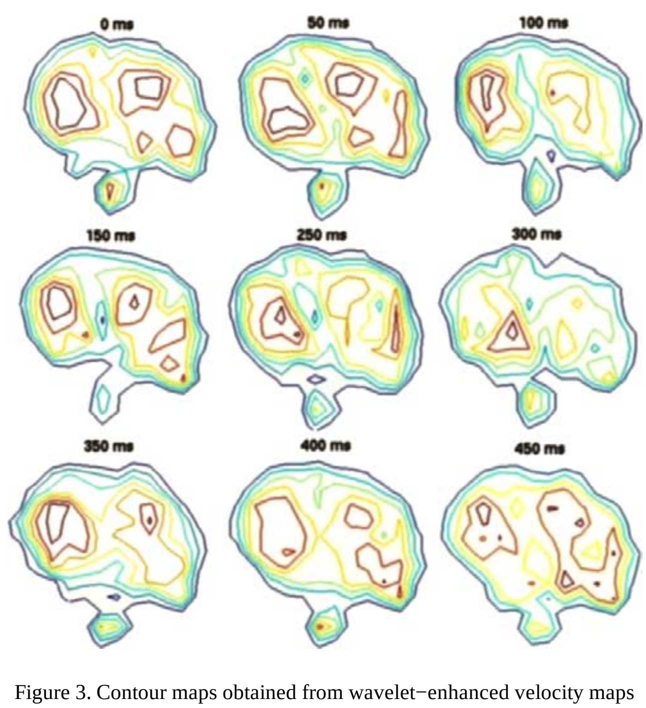

Figure 3. Contour maps obtained from wavelet−enhanced velocity maps from Fig. 2 are illustrated. Hemodynamic patterns can be observed that might characterise the hemodynamics of a healthy heart and descending aorta.

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